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TITLE: Magnetic resonance imaging device

Abstract Paragraph:
An MRI apparatus suitable for realizing selective excitation utilizing multiple RF transmitting coils (parallel transmission) is provided. This MRI apparatus is provided with, as an RF receiving coil or RF transmitting coil, an RF transmitting coil 104 comprising a loop coil 210, primary differential coil 220 and secondary differential coil 230 having a common central axis 201. Upon imaging, the coils 210, 220 and 230 constituting the RF transmitting coil 104 are simultaneously driven by RF signals with the same phase, and only the differential coils 220 and 230 are driven in the second half of irradiation time with phases different by 180.degree. from the phases for the first half. Alternatively, two times of measurements are performed as a pair, in which, in the first measurement, the coils 210, 220 and 230 are simultaneously driven with RF signals of the same phase, then in the second measurement, only the differential coils 220 and 230 are driven with phases inverse to the phases for the first measurement, and the signals measured respectively are added. Such imaging or addition of the results of two times of the measurement provides a profile for exciting a local region. This enables selective excitation of only a desired region without using any RF pulse for signal suppression.

Brief Summary Text:
[0005] In the MRI apparatus of the present invention, the aforementioned object is achieved by performing specific irradiation phase control for the RF magnetic field. That is, the MRI apparatus of the present invention comprises a transmitting means for applying an RF magnetic field to a subject placed in a static magnetic field, an RF irradiation control means for controlling irradiation phase of the RF magnetic field, a receiving means for detecting nuclear magnetic resonance signals generated from the subject, a control means for controlling the transmitting means, the RF irradiation control means and the receiving means, and an image formation means for reconstructing an image of the subject by using the nuclear magnetic resonance signals, and the MRI apparatus is characterized in that the RF irradiation control means

controls RF irradiation so that the RF **pulse** should be applied with a **phase** of the second **half** of the RF **pulse waveform** after the **center thereof different** by 180.degree. from the **phase** of the first **half** of the same.

Brief Summary Text:
[0007] In the MRI apparatus of the present invention, the transmitting means is provided with a multiple array transmitting coil comprising multiple coils of **different** irradiation intensity profiles, and the RF irradiation control means performs such **phase** control for a part of the multiple coils that the **phase** of the second **half** of the RF **pulse waveform** after the **center thereof should be different** by 180.degree. from the **phase** of the first **half** of the same.

Brief Summary Text:
[0010] In the MRI apparatus provided with the multiple array transmitting coil having such differential coils, the RF irradiation control means performs such **phase** control for a differential coil part of the multiple coils that the **phase** of the second **half** of the RF **pulse waveform** after the **center thereof should be different** by 180.degree. from the **phase** of the first **half** of the RF **pulse waveform**.

Brief Summary Text:
[0014] In addition, it is also possible to perform **phase** control only for the differential coils so that the **phases** of the RF **pulse should different** by 180.degree. in two times of the measurement instead of performing **phase** control so that **phases** of the first **half** and second **half** of the RF **pulse** irradiation should be **different** by 180.degree., and add NMR signals obtained by two times of the measurement to reconstruct one image. Also in this case, the same effect can be obtained as the case where **phase** control is performed so that **phases** of the first **half** and second **half** of the RF **pulse** irradiation should be **different** by 180. degree..

Brief Summary Text:
[0016] Also in the MRI apparatus having such a configuration, an image of a selectively excited region can be obtained by performing RF transmission with **phases different** by 180.degree. for the first **half** and second **half** of one time of RF **pulse** irradiation, by performing imaging with such **phase** control two times with inverse **phases** and adding NMR signals obtained by two times of the measurement to reconstruct one image, or by performing RF transmission with **phases** of RF **pulses different** by 180.degree. in two times of measurement and adding NMR signals obtained by two times of the measurement to reconstruct one image.

Description of Disclosure:
[0061] Hereafter, an MRI apparatus provided with a selective excitation function will be explained as an embodiment of the MRI apparatus of the present invention. This MRI apparatus uses a combination of multiple **RF** coils having different irradiation intensity profiles as the **RF** transmitting coil 104 and **simultaneously** drives these multiple coils to provide a specific **excitation** profile. As the multiple coil system, **one** comprising a plurality of partial coils each having different irradiation intensity profile and no magnetic coupling can be used, and for example, multiple coil systems having the structures shown in FIG. 2 and FIG. 4 are preferred.

Description of Disclosure:
[0064] In the selective **excitation** imaging method of this embodiment, an **excitation pulse** 601 is **simultaneously** transmitted from three of the coils of the aforementioned **RF** transmitting coil 104 (**parallel** transmission). In this transmission, the **phase is changed** during transmission of **one** RF **pulse** for the differential coils. Specifically, as shown in FIG. 7, the RF transmission is performed so that the RF coils 210, 220 and 230 constituting the RF transmitting coil 104 should perform the RF transmission with the same **phases,** i.e., 0-0, for the first **half** of the irradiation time of RF **pulse** 601 (the portion before the **center** indicated with a solid line), whereas, for the second **half** (the portion after the **center** indicated with a dotted line), the RF transmission should be performed with a **phase changed** by 180.degree. only for the differential coils 220 and 230 and with the same **phase** as that of the first **half** for the loop coil 210. The other gradient magnetic fields (slice selection gradient magnetic field 602, slice encoding gradient magnetic field 6031, **phase** encoding gradient magnetic field 6032 and frequency encoding gradient magnetic field 604) are applied in the same manner as in a common gradient echo sequence, and a step of applying an RF **pulse** and measuring an echo signal 605 after an echo time TE is repeated for a required times while **changing** intensities of the slice encoding gradient magnetic field 6031 and the **phase** encoding gradient magnetic field 6032 to collect echo signals 605 in a number required to reconstruct an image.

Description of Disclosure:
[0066] When the RF **pulse** 601 is simultaneously RF-transmitted from three of the coils of the RF transmitting coil 104, the sum of the signals generated from spins **excited by each pulse** is received by the RF receiving coil 105. If the flip angle of the RF **pulse** 601 is represented as .alpha., spins are inclined by .alpha./2 in the first **half** and further inclined by .alpha./2 in the second **half,** thus by an angle of . alpha. in total, by the irradiation of RF **pulses** described above at the

central portion of the RF transmitting coil 104, and therefore desired **excitation** is attained. On the other hand, at the peripheral portion as for the axial direction of the RF transmitting coil 104, which is exposed to irradiation from the differential coils, spins are inclined by .alpha./2 in the first **half** and by -.alpha./2 in the second **half,** thus the spins are not eventually inclined, and no **excitation** is attained. Referring to FIG. 8, when the RF **pulse** is applied with the same **phase** by three of the RF transmitting coils, the **excitation** profile is as shown in FIG. 8 (a), and when the **pulse** is applied with **phase change** of 180.degree. only for the differential coils, the **excitation** profile is as shown in FIG. 8 (b). If only the **phase** of the RF **pulse** applied to the differential coils is differed for the first **half** and the second **half** of the irradiation time as in this embodiment, when the first **half** is completed, i.e., at the **center** of the RF **pulse, the excitation** profile is as shown in FIG. 8 (a), and after that, when the whole RF **pulse** is applied, the **excitation** profile finally becomes as indicated with a bold line in FIG. 8 (c), which is a profile (profile shape) as if only the central portion along the central axis of the RF transmitting coil 104 is **locally excited**. That is, the echo 605 obtained by such **phase** control as described above is a signal from a **region selected** along the **phase** encoding direction Gp or along the frequency encoding direction Gr (direction of the central axis of the RF transmitting coil 104). With the sequence shown in FIG. 6, the **slice** gradient magnetic field 602 is applied upon the RF transmission, and the **selection** was made along the **slice** direction Gs. Therefore, two-dimensional **selective excitation** for the Gp-Gs **plane** or Gr-Gs **plane** is realized.

Description of Disclosure:
[0070] As described above, according to this embodiment, **selective excitation of a local region** can be easily attained with a sequence exactly the same as those used for existing techniques only by performing the control for differentiating the phase of the RF pulse for the first half and the second half of the irradiated waveform. This enables imaging and display of a small **region** with high speed, high resolution and suppressed artifacts.

Description of Disclosure:
[0072] That is, in each of two times of the measurement performed with the same encoding, during the transmission of the RF **pulse** 601, the RF **pulse** is applied to the differential coils 220 and 230, for the second **half** of the irradiation time, with a **phase different** by 180.degree. from the **phase** for the first **half** of the irradiation time. Further, in the second measurement, the RF **pulse** is applied with a **phase different** by 180.degree. from the **phase** for the first measurement only for the

differential coils 220 and 230. Then, the echo signals obtained in the first and second measurements are added and used as data of the **phase** encoding.

Description of Disclosure:
[0073] More specifically, for example, the RF **pulse** for the first measurement is applied to the loop coil 210 and the differential coils 220 and 230 with a **phase** of 0.degree. for all the coils in the first **half** of the irradiation time, and in the second **half** of the irradiation time, the RF **pulse** is applied to the loop coil 210 with the same **phase,** i.e., 0.degree., and to the differential coils 220 and 230 with a **phase** of 180.degree. (i.e., **different** by 180.degree. from that for the first **half**). Then, the RF **pulse** for the second measurement is applied to the loop coil 210 with the same **phase,** i.e., 0.degree. and to the differential coils 220 and 230 with a **phase** of 180.degree. (i.e., **different** by 180.degree. from that for the first **half** of the first measurement) in the first **half** of the irradiation time, and in the second **half** of the irradiation time, the RF **pulse** is applied to the loop coil 210 with the same **phase,** i.e., 0.degree., and the differential coils 220 and 230 also with the same **phase,** i.e., 0.degree. (i.e., **different** by 180.degree. from that for the second **half** in the first measurement and **different** by 180.degree. from that for the first **half** in the second measurement).

Description of Disclosure:
[0076] Hereafter, the third embodiment of the MRI apparatus of the present invention will be explained. The pulse sequence of FIG. 6 may be also employed as the pulse sequence for this embodiment. In this selective excitation imaging method, measurement is performed twice for the same encoding with differently performing the phase control, and the results of two times of the measurement are added to reconstruct **one** image. That is, in the first measurement, the **excitation** pulses 601 is **simultaneously** transmitted with the same phase by using the **RF** transmitting coil 104 comprising three of the aforementioned coils 210, 220 and 230 (**parallel** transmission). Unlike the first and second embodiments, the phase is not changed during the irradiation time for **one** time of irradiation. In the second measurement, the transmission is performed with a phase different by 180.degree. from that for the first measurement only for the differential coils 220 and 230. The other gradient magnetic fields (slice selection gradient magnetic field 602, slice encoding gradient magnetic field 6031, phase encoding gradient magnetic field 6032 and frequency encoding gradient magnetic field 604) are applied in the same manner as a common gradient echo sequence.

Description of Disclosure:
[0081] The sequence shown in FIG. 10 is the same as the sequence shown

in FIG. 6 except that the slice selection gradient magnetic field to be applied simultaneously with the RF **pulse** 601 is excluded. Instead, in this embodiment, imaging is performed by using the direction of the central axis of the RF transmitting coil x-axis) as the slice direction. Also in this case, **phase** control is performed according to any one of the following schemes (1) the RF **pulse** 601 is irradiated with **phases different** by 180.degree. for the first **half** and the second **half** of the irradiation time only for the differential coils, (2) imaging is performed twice by irradiating the RF **pulse** 601 with **phases different** by 180.degree. for the first **half** and the second **half** of the irradiation time only for the differential coils, and the **phases** for the differential coils should be inverse in two times of the measurement, and (3) the first measurement is performed with the same **phase** of the RF **pulse** 601 for all the coils, the second measurement is performed with a **phase different** by 180.degree. only for the differential coils, and echo signals obtained by two times of the measurement are added.

Description of Disclosure:
[0086] FIG. 11 shows another embodiment of the RF transmitting coil, and it has the same configuration as that of the RF partial coil 420 as one of the coils in the RF coil 400 shown in FIG. 4 (FIG. 4 (c)). That is, this RF transmitting coil 1500 is constituted by two sets of RF partial coils 1510 and 1520 (four loop coils 1511, 1512, 1521 and 1522), which have a common central axis 1531 and are **plane**-symmetrically disposed with respect to the **plane** 1532 perpendicular to the central axis 1531. The RF partial coil 1510 has a flat and wide irradiation intensity profile represented by a curve 1515, and the RF partial coil 1520 has a sensitivity profile represented by a curve 1525, which is a narrow sensitivity profile in which sensitivity is 0 at the **plane** 1532 and has different polarities on the both sides of the **plane,** as shown in FIG. 11 (b). These RF partial coils 1510 and 1520 are independent from each other and do not interfere each other, because the **volume** integral of the product of the generated magnetic field and sensitivity profile is 0. As will be seen on the analogy of the explanation of the **selective excitation** by the RF transmitting coil of FIG. 2 (FIG. 8), as a result of **selective excitation** according to the present invention using the RF transmitting coil 1500, an irradiation intensity profile which **locally excites** the central portion of the coil is obtained. Because this RF transmitting coil 1500 is not provided with a secondary differential coil, sharpness of an end (edge) of a **region to be selected** is inferior to that obtained with the RF transmitting coil of FIG. 2. However, because it has a configuration that a pair of loop coils 1511 and 1512 are disposed at the center with an interval, it is suitable for **selective excitation of a region** larger for the central axis direction compared with the RF transmitting coil of FIG. 2. Further, because two of the loop coils 1511 and 1512 can be disposed so that a **region** to be

imaged should be between them, it has an advantage that they can be easily put on the subject.

CLAIMS:

1. A magnetic resonance imaging apparatus comprising a transmitting means for applying an RF magnetic field to a subject placed in a static magnetic field, an RF irradiation control means for controlling irradiation phase of the RF magnetic field, a receiving means for detecting nuclear magnetic resonance signals generated from the subject, a control means for controlling the transmitting means, the RF irradiation control means and the receiving means, and an image formation means for reconstructing an image of the subject by using the nuclear magnetic resonance signals, wherein the RF irradiation control means controls RF irradiation so that the RF **pulse** should be applied with a **phase** of the second **half** of the RF **pulse waveform** after the **center thereof different** by 180.degree. from the **phase** of the first **half** of the RF **pulse waveform**.

2. The magnetic resonance imaging apparatus according to claim 1, wherein the transmitting means is provided with a multiple array transmitting coil comprising multiple coils of **different** sensitivity profiles, and the RF irradiation control means performs such **phase** control for a part of the multiple coils that the **phase** of the second **half** of the RF **pulse waveform** after the **center thereof should be different** by 180.degree. from the **phase** of the first **half** of the RF **pulse waveform**.

7. The magnetic resonance imaging apparatus according to claim 3 or 5, wherein the RF irradiation control means performs such **phase** control for the differential coil among the multiple coils that the **phase** of the second **half** of the RF **pulse waveform** after the **center thereof should be different** by 180.degree. from the **phase** of the first **half** of the RF **pulse waveform**.

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